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SCIENCE AND TECHNOLOGY IN EASTERN EUROPE AFTER THE FLOOD: REJOINING THE WORLD

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I. INTRODUCTION

The flood metaphor describes the situation the science and technology practitioners of Eastern Europe now find themselves in.[1] The economic, political, institutional and cultural foundations upon which their working environment was predicated have been all but swept away. Especially for the East Europeans, who unlike their Soviet colleagues cannot entertain any illusions about their countries' R&D systems being sustainable as more or less independent entities, the next years will mean a startling period of transition. The transition will not only be one of domestic institutions, but of fundamental orientation as well. East European science and technology[2] needs to rejoin the global mainstream to survive and to be effective. This paper discusses the means for doing so and the problems to be faced.

Students of Soviet and East European affairs are occasionally guilty of parochialism. This may also be said of analysts of the region's science and technology systems. Phenomena appearing to be satisfactorily explained by the peculiarities of orthodox Soviet-type institutions are sometimes not taken beyond the context of the local situation. Certainly, if the temptation to view all behavior as a result of system-specific institutions was great before, it receives reinforcement now as the systemic character of the general crisis becomes more stark. Yet, if the forces affecting the science and technology establishments in these countries are not viewed as part of larger, worldwide phenomena, some of the subtleties may be missed.

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[1]This paper was presented at a conference on "Technology, Culture and Development: The Experience of the Soviet Model," held at Ohio State University, Columbus, Ohio, 26-27 October 1990.

[2]The phrase "science and technology" will be used in this paper to connote a unitary system for generating the familiar outputs of research results, both basic and applied, and technological development. Hence the use of the singular verb. By Eastern Europe, I refer to the five states remaining from the former CMEA Six: Bulgaria, Czechoslovakia, Hungary, Poland, and Romania. The situation of the former German Democratic Republic is a special case.

An example of this is the interpretation of the CMEA (Council for Mutual Economic Assistance) Comprehensive Program (hereafter, "the Program") for Science and Technology to the Year 2000, signed by the heads of government in Moscow, December 1985. Its existence and origin would seem to be adequately explained by the autarkic nature of the economic systems prevailing in each member state, the closed and hierarchical character of national science establishments, and the previous record of CMEA in attempting to erect monstrosities of planning and coordination in a wide range of fields. Yet, at the same time, it cannot be entirely coincidental that one of the emergent themes in contemporary research, both basic and applied, throughout the world is increasing multilateralization and internationalization of research efforts in a wide range of fields. To fully appreciate the changes required of the East European science and technology systems to meet the challenges of the post-Communist future, the systems must not be viewed solely as reacting to the malignancies of what has gone before on the local scene. They need also be analyzed for their viability as mechanisms for meeting the challenges being posed to science and technology organizations everywhere. In this light, this paper will consider the necessary changes needed to preserve the scientific tradition in Eastern Europe in the face of the recent upheavals and to implement rejoining, in the fullest sense, the mainstream of the world scientific community.

A WIDER VIEW OF CONTEMPORARY SCIENCE

Although generalizations must be used with caution, several trends in the management and application of science are apparent across national frontiers and across systems. One appears to be the shift from viewing science as the "endless frontier," with ever-expanding scope and horizons, to seeing it as a constrained steady-state system forced to confront stringencies in funding allocations and limits to human and material resource endowments.[3] While one may certainly argue about the

[3]The steady-state theme is owing to John Ziman (1987). Whether a general "limits to growth" model of science is universally applicable is open to dispute. The latter would appear not to allow for changes in

applicability of this image to individual countries, the general environment surrounding scientific pursuits often has a different feel than was the case in the 1950s and 1960s. Concern over government deficits and the accompanying need to trim subsidies by cutting back or placing former recipients of state subventions onto a self-financing basis are not solely Soviet or East European phenomena. This school of thought would argue they are manifestations of a worldwide, perhaps irreversible, structural change in the management, organization, and performance of science (Ziman, 1987).

Coupled with this shift is a second major global trend: making science pay its way. Pressure is being placed on the science system externally by heightened expectations for the potential contribution from the science and technology base to national welfare. The code words are "science policy" and even "strategic science," but the real issue is international competitiveness reflecting a near universal concern for preserving or securing market share in several high technology areas in the face of formidable pressures for reduction.[4] Science itself, then, is not the real object. Rather, these policies are driven in part by a paradigm viewing science as the progenitor of technological advance and the mainspring of the technology system. This theme and its problematic nature will be explored below in a slightly different context. The central tenets of strategic science are recapitulated on all continents, in both developed and developing countries, in technological leaders as well as among traditional technology followers.

A third trend stems partially from the first two. In an era where there is at least a perception of growing resource constraint and where, at the same time, great expectations are placed upon even fundamental

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forms and institutions, and it abstracts the science system from the background of the larger systems within which it is contained and which might also be transforming. Yet, the image certainly seems to capture many of the strains afflicting science today.

[4]The phenomenon of shrinking market shares may be more statistical than economic in character: a larger number of technologically competent exporters necessarily means a smaller proportional slice for almost all players.

basic research, scientific and technological pursuits appear to be becoming more multilateral and international in several disparate fields.[5] Pooling of resources, especially in big-ticket scientific fields, would seem prudent. Further, becoming a member of a consortium appears to be a method of writing a partial insurance policy if competitiveness based upon any ensuing applications is a concern. A consortium member gambles its opportunity for gaining exclusive rights over any useful discoveries against the greater likelihood of being assured some slice of whatever issues from the cooperation.[6] Beyond these concerns, there is also a growing awareness that the public affected by the public good aspect of scientific knowledge is more than just the domestic population of the country where original research is performed. Further, much of the impact, for good or for ill, necessarily carries across national frontiers. If any progress is to be made in several of the more pressing areas of concern addressed by science today, the effort must, as a matter of course, be international since the potential solutions are almost certain to be so.

It remains to be seen whether this trend is a harbinger of the future or a passing fancy which will prove incapable of handling the strains brought on by the conflicting incentives inherent in any cooperation, especially as one draws closer to the applied end of the research continuum. Further, a considerable impetus comes from possibly transitory national political considerations such as a desire to signal a willingness for closer cooperation among Europeans. For the present, the tendency is toward greater internationalization. In this respect, the CMEA Program appears less an aberrant attempt at intruding late

[5]In the ten years between 1976 and 1986, the fraction of scientific papers by French, West German, U.S., and Japanese scientists that were internationally co-authored at least doubled (Perry, 1990).

[6]This phenomenon is not found exclusively in the domain of public efforts. In the private sphere, there is also a trend to bring smaller pieces together to form cooperative industrial R&D efforts. The growing perception (almost certainly erroneous) is that competition on the international level may be more important than domestic competition. This has led to pressure on long-held policies designed to promote pluralism and decentralization.

Brezhnevite ideals of socialist internationalism into the world of scientific research, and more consistent with global trends.[7] In fact, four of the Program's five main research areas – microelectronics, automation, new materials, and biotechnology – are recapitulated in virtually every other multifaceted international research effort, such as EUREKA, ESPRIT, BRITE, RACE, CERN, ESA, and even SDI.[8]

The organizational arrangements for the modern science regime are still fluid and require greater definition. Decisions based upon current policies will crystallize them. If there truly has been a secular shift in the relations between established science and larger society, there is probably no way back to the traditional arrangement; but there are as yet many different ways forward. What is needed in such a system is a way to provide accountability, efficiency, excellence in performance, exploitable outputs, and adaptability to change while preserving individual creativity, time for ideas to mature, openness to criticism, hospitality to innovation, and respect for specialized expertise. The shifts required in Eastern Europe are no less and the need at least as great. They may be viewed as a special, if acute, case, if not a quintessence of the shift occurring on a global scale.

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[7]This is not to suggest all members of CMEA were equally eager to join the Program. On this point see Popper (1991).

[8]The fifth area, nuclear energy, was out of fashion in the West at the time many of the more recent consortia were formed, but it was certainly among the earliest areas of cooperation. The first large, permanent international cooperation in research was CERN.

II. THE DELUGE

The challenge facing Western science establishments is how to conserve the cherished values enumerated at the end of the last section in the face of a changing environment. The problem facing the East Europeans is how to deal with the same set of external pressures and demands while at the same time somehow rebuilding many of the values they once held in common with other scientific communities, destroying the institutions of forty years in the process. The problem of transition in Eastern Europe is therefore twofold, involving a process of creative destruction on a scale unmatched elsewhere. It is given greater urgency because the continued existence of many scientific establishments in the region may by no means be taken for granted.

The structure of the science and technology establishments of Eastern Europe will be familiar to students of Soviet R&D and need no detailed elaboration here. A major defining element is the Academy of Sciences system. Fundamental research is performed in Academy institutes and not in the universities, whose principal responsibility is teaching. Applied research, in turn, is largely conducted within the parallel system of ministerial R&D institutes organized by industry. This design assumes the presence of a well-informed central authority actively guiding research efforts to maximize the resources available to society. In practice, the result is more often considerable fragmentation of effort because of compartmentalization, so that even applied work quite often does not address the real needs of the clients.

Another characteristic was, of course, the political and ideological intrusion into personnel and priority allocation decisions present in all countries of Eastern Europe to varying degrees. This was reinforced by the nature of financial support of science and technology. Although principles of self-finance had entered into the R&D systems of several countries, for most practical purposes institute working funds were allocated from the central budget.

A further legacy of the past is the insufficiency of information available to practitioners, particularly at the applied end of the R&D spectrum. Price information computed by internal accounting systems not suited to the needs of institutes and enterprises, combined with contrived systems of incentives, has led to poor technology choice and inefficient utilization of R&D resources. This aspect of the former system has been a greater factor in denying Eastern Europe the practical fruits of technology than was COCOM.

PROBLEMS OF TRANSITION

The system as it has existed will not continue to serve the needs of East European science and technology establishments. Many factors will be forcing change.

Economic

Clearly, as with other East European institutions, many of the greatest problems will stem from the general economic crisis coupled with the need to transform the economic systems to market-based ones more responsive to present needs.

Among other things, this will mean a funding crisis. As part of a macroeconomic stabilization package, each country will be reducing central expenditures from which resources for fundamental and applied research have almost exclusively come. This break will be even more sharply felt because, in the past, the fortunes of basic science have corresponded with the fortunes of defense establishment budgets. There is no question about the plunge these will take in the short to medium term.[1]

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[1]This will not be an entirely new experience. There has been increasing anger among especially the younger generation of researchers over centrally mandated funding cuts in light of worsening economic crisis. This led, in Hungary, to founding the first independent trade union since Solidarity, after research spending was slashed by 25% in December 1987 (*Science*, vol. 240, 27 May 1988, pp. 1142-1143). In retrospect, this was an important step in the fall of the regime. Poland's Third Science Congress in May 1986 was also an explicit recognition of the crisis of funding.

Science establishments will be asked to become self-sustaining as much as is practical (and perhaps even more than that). But here will lie the rub. While the need for economic stabilization is clear and pressing, the transformation of the economic apparatus to a new form is likely to take time and is even sometimes viewed as a later stage of the process.[2] In fact it is integral. If scientific institutions are forced to rely upon their own resources, there must be an external and internal environment making this possible. In large measure this milieu does not exist. Both inside research institutions and in industry as well, there remain fundamental problems of a systemic character in supporting risk-taking behavior by researchers, developers, and would-be innovators. These will not be resolved before there is a profound shift in the nature of the information available to decisionmakers (i.e., a price system reflecting true scarcity values and real resource costs) and a change in the incentive structure confronting them. This shift, in turn, will require a radical redefinition of ownership rights, likely to be the most contentious and knotty problem faced during economic transition. Yet, it is the source of the chronic, systemic failure to create applications from research findings. This will not change without a complete redrafting of the system within which the relevant decisions are made.

Too drastic an application of the tenet of self-financing of research could also adversely affect the research programs of East European science. There is danger of forcing too short-term an approach on research, thereby reducing more fundamental and theoretical pursuits while increasing the potential cost of attempting major leaps. Whether this outcome might not be desirable is a question of policy to be treated below.

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[2]Cf. the general Gorbachevian/Ryzhkovian reform strategy in the Soviet Union through the summer of 1990.

Political

The revolutions in domestic politics are also reflected in the world of science. In particular, the general crisis of authority caused by changing concepts of legitimacy ushered in by the revolutionary changes of 1989 has left serious rifts within the microcosm of the academy system and its research organs. Strains have developed between the young research workers who have imbibed deeply the spirit of '89 and their section heads and institute directors who are viewed as often having gained their place through obsequiousness and political rectitude rather than scientific aptitude or managerial ability.[3] The attempts of the latter to quickly trim their sails to catch the new wind and maintain their positions have led to considerable preoccupation with internal politics at the expense of scientific endeavors. There is a need to normalize the situation by bringing the legitimacy of institute leadership into accord with the prevailing notions of pluralism, democratic process, and merit. At the same time, existing institutions can take only so much disruption. This tension between change and preservation will be one of the strongest undercurrents in the political and social life of East European research institutions in the near term.

The internal crisis of authority may well be matched by a challenge to the authority of science within the society as a whole. Again, a tendency toward the abuse of science and its practitioners, after their having been placed on the pedestal of official civic (socialist) virtue for so long, would be a local ripple of a larger current taking place outside Eastern Europe as well (Teich, 1990). In the West, this abuse is not fundamental. Science is called to task on issues of animal rights, falsification of data and research, and participation in weapons research, to name a few specific cases. It still retains some blanket protection of its authority because it is largely viewed as being

[3]This is true in the countries with a more liberal outward aspect as well as in such repressive states as Romania and Bulgaria. Hungary appears most easily to be effecting leadership changes. In Czechoslovakia, where changes in the academic hierarchy have been more sudden, and in Poland, where the phenomenon of "trimming" is more pronounced, resolution may be farther off.

a-political and objective. In Eastern Europe, however, where one of the single-party regimes' claims on the right to rule was their ability to accelerate the pace of progress by bringing science to bear in a planned and coordinated manner on the problems attending the creation of national wealth, scientists may not find themselves so insulated. Science and the scientific establishment were closely identified with the old communist order in each country of the region. This may well cause a falloff in the prestige of science in the short term, especially as the full range of problems left strewn in the wreckage of the old regimes becomes more clear to the public.[4] The practical effect might be large if it leads to pressure to close facilities or to even more draconian cuts in central budget allocations already due for considerable slashing.[5]

The cadre problems manifested in the phenomenon of brain drain partially reflect the discrediting of the existing scientific establishment and partially the general loss of prestige of science, but they cut across several other themes as well. The ability of East European establishments to retain and effectively utilize trained personnel is in question. This theme will be treated in a wider context below.

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[4]This is perhaps most likely in Czechoslovakia, where in distinct contrast to popular rhetoric about democratic traditions, the reality of the last 22 years has been one of a repressive regime heavily compromising those with any position or prominence within society.

[5]Chemical industry research workers may be especially hard hit as vast tracts of the region's chemical industry is forced to close because of outmoded, inefficient, and severely polluting facilities. If they do remain open, plants will need to convert to more modern, less polluting synthetic processes. For example, East Germany's vast capacity for producing methanol, a low value-added product, may be used to make acetic acid for export rather than to use the old acetylene/acetaldehyde process, which entails use of dangerous mercuric sulfate for catalysis (O'Sullivan and Lepkowski, 1990).

The Crisis of Institutions

The economic and political problems of East European science will provide the background for the major task of reformulating or rebuilding anew the institutions which are to govern, direct, and judge the results of scientific research in each country. Many would wish for stability in the political and economic environment so this business could proceed in a deliberate and considered fashion rather than be forced in an atmosphere of crisis. Yet it may well be that the revolutionary temper of the times may allow, and indeed may force, a more profound reorganization than might otherwise be the case.

The questions to be answered are truly fundamental. How does one encourage autonomous decisionmaking in such formerly centralized systems? Basic approaches to funding, project choice, technology assessment, and assignment of priority will need redrafting as the hierarchies governing these decisions are replaced.

Especially during the era of diminished resources Eastern Europe is now entering, there must be decisionmaking, using yet-to-be-specified means, to assess where assets are best allocated while at the same time introducing new flows of information from lower-level units. Yet, Eastern Europe carries the legacy of the past: Concepts and mechanisms for peer review, both *ex post* in assessment and *ex ante* in project choice, have either never existed or have lain dormant for forty years or more. Networks of contacts existed and continue to exist, but these often are based more on political calculation than acknowledgement of expertise and are coming under increasing pressure as change sweeps over these societies.

Priority will need to be assigned not only to individual projects but to entire institutes as well.[6] In doing so, the East Europeans may

[6]For many East European scientists, this may smack of the old research "problems" approach applied in a hierarchical fashion in Poland in the 1970s under science minister Kaliski, which was viewed as both wasteful of resources and injurious to infrastructure (*New Scientist*, 12 May, 32-33). Hungary, on the other hand, may once again prove to be in the vanguard in reapproaching Western practice. In 1987, the new Hungarian Research Foundation instituted a competitive system for awarding grants to fund basic research (*Science*, 15 May 1987, 770-771). Nevertheless, the culture of the past was hard to shake, and there were many charges of the 'old boy' system protecting its own.

suffer from a lack of direct experience with other models of organizing and sustaining R&D work and training because of travel and other restrictions that were in place for the entire working lives of virtually all current practitioners.

There may also be a more subtle institutional handicap. The intellectual and institutional architecture of the Soviet-type economies' *science and technology* system, taken as a whole, and in particular the perception of how science relates to technology, may perhaps be particularly ill-adapted to the process of transition.

The point may be illustrated by postulating the existence of two identifiably different systems for defining the relationship between science and technology. The first analogizes from the apparent experience of the Second World War where science-derived weapons such as radar, sonar, and the atomic bomb, to name but a few, were the source of technological supremacy and ultimate victory. This view, in its extreme, would hold technology to be an appendage of a system driven by basic science. Process is linear: Fundamental findings about natural law lead to applied findings that are then taken by technologists to be developed into specific applications. Implicitly, this creates a *de facto* caste system. High-*pukka* Science pushes back the frontiers defining the limits of human knowledge while lower-caste Technology follows in its course, making use of what is left in the wake of pathbreaking research.

There is, of course, a good deal of caricature in this exposition. Yet it does capture the essentials of a philosophical system prevailing in many avenues. In part, it provides the intellectual foundation behind calls to "make science pay" by marshalling strategic science policy to contest for economic competitiveness. Such a view argues that the scientific revolution has finally come into its own in this century. However, in positing such linearity, this paradigm may overstate the dominant role of science and minimize the complex relationship between it and technology.

We may identify a second paradigm, opposed to the linear, science-driven one, which does not make the scientific revolution as central an event. Rather, it would recognize science, the path of accumulating knowledge by organized conjecture, and technology, the path of accumulating knowledge by making, as two discrete, if highly integrated, avenues of human progress, each with a long-shared history but with technology possessing the longer independent existence. In this view, it is less certain which is the tail and which the dog. In fact, an extreme position would relegate science to the position of exploring the new worlds which technological developments in machine-making and instrumentation have disclosed.[7] It is certainly quite often the case that technology enables science by presenting it with new problems, on the one hand, and new tools for observation on the other. A science and technology system built upon this latter view would be less caste-oriented, and organizations would be designed to admit the possibility of useful notions being generated in either sector and then jointly developed by input from both.[8]

The suggestion to be derived from these two postulated approaches is that it is possible for a science and technology system organized according to the first set of principles to generate an impressive store of knowledge and Nobel prizes while gradually losing market share and competitive position to other systems admitting of more complicated feedback relations between two more or less free-standing approaches to mastering nature. For the present purpose, a hypothesis may then be derived. The system of Soviet science and technology, and by transplantation that of the East Europeans, may be more accurately

[7]For example, thermodynamics arose as a means for explaining the phenomena accompanying the invention of the steam engine. The vast bulk of research in solid state physics and in coherent light emission occurred after the inventions of the transistor and the laser. Biotechnology has grown out of molecular biology, to be sure, but that in turn grew out of genetics, which derived from observations based upon practical experience with plant and animal breeding.

[8]It would probably be too categorical to associate this view generally with the losers of the Second World War: Japan, Germany, and perhaps even Italy and France. The temptation, however, is there.

modeled by the first set of postulates than by the second. This may have been partially conscious, with the Soviets seeking to follow in the path of those nations that the Hegelian process of history had determined to be winners.[9] In part, this paradigm may have come by default as a derivative of the Soviet system's first principles for general economic and social organization. In a strictly hierarchical system of centralized control, where power is held by one group because of their claim to a uniquely acute understanding of history, there would be a natural gravitation to a philosophical construct that provided a simple, unidirectional model for technological interaction. The planned economy bespeaks commitment to a linear view of process. The fact that in some East European countries, as will be explored below, science could be identified with the coming to power of the communist regimes would strengthen this predisposition.

Is it accurate to characterize the science and technology systems of Eastern Europe in this manner? After all, the dual existence of both academy and industrial ministry R&D institutes would seem to pay court to the notion of two free-standing structures for technology development. And wasn't there always a strong predisposition on the part of the political leadership to bring science to the service of the economy by supporting technological development, even to the detriment of long-standing traditions of excellence in basic research? Definitive answers can only be forthcoming after further study. However, the distinction between the two systems developed above does not lie solely or even largely in the difference between a unitary linear system and one where there formally exist two parallel hierarchies. Rather, the difference would be characterized by the degree of complexity permitted in the interactions between the structure of science and that of

[9]After the First World War the Soviet Union sought to develop most fully those industrial sectors they identified as being characteristic of the war's winner, the United States, rather than those they identified as being more highly developed in the loser, Germany (see Bailes, 1978, for a discussion). Similarly, the apparently science-led mastery of the British and Americans over Germany again in the Second World War may have led to linear conclusions about the role of science in developing technology.

technology; between linear interaction along a well-defined time course and interaction that is more frequent, less well-scheduled, and where the direction of flow and influence is much more complex than the linear model would suggest. Here, the near hermetic closure of the dual academy and ministerial systems of research and the near inadmissibility of either being equally likely to have a profound influence on the other would mean a linear type of interaction would be the best that could be hoped for. Anything more complex could not be supported by the existing structure. The essence of the more complex version would be realized not in two hermetically closed structures, but rather in two sets of institutions, free-standing in some respects yet each vitally dependent on the other in ways too complex to adhere to any simple formulation of precedence. Beyond this, the very existence of an identifiable political predisposition to make science the driver for technological development provides a second marker.

The suggestion is not that this approach is wrong in every circumstance or even in fundamental concept. Rather, for the purpose of supporting technological development, especially in an era of profound transition such as Eastern Europe is now experiencing, it provides a more restrictive set of possibilities for organization and interaction and so may be more likely to prove nonadaptive in certain fields or environments.

HOW DOES EAST EUROPEAN SCIENCE AND TECHNOLOGY DIFFER?

Much, if not all, of what has been said above could apply to the Soviet case as well. This is certainly not surprising. Even though Eastern Europe was always too diverse a region to be accurately spoken of in the general terms usually dictated by expediency, in few spheres was the Soviet model so faithfully recapitulated as in the area of organization and administration of science. Are there, then, identifiable differences affecting the qualitative aspects of the transition problem?

There are two obvious areas of difference. First, the East Europeans would appear to fall into two classes. There are those who, like the Soviet Union, have an independent scientific tradition of some long standing (East Germany, Poland, and Hungary are certainly among them) and those like Bulgaria and Romania whose scientific tradition stretches back less far and whose domestic scientific communities are more a development of, or are contemporaneous with, the communist era. While such a generalization is heroic in its scope, this factor may prove to be of more than historical interest. The distinction is not intended to impugn the native genius of the Bulgarian or Romanian peoples or to disparage their ability to produce scientists of great stature. Rather, it suggests there may be greater difficulty in generating rank-and-file scientific workers who nevertheless are able to make a contribution of significance in global terms.

Further, to the extent the others possess a scientific tradition more closely bound to the West, it may be easier to make the transition back to what for them will be an older system of organization, but one with which they can identify and for which they retain at least institutional, if not personal, memory. The transition may prove more difficult in countries where science traditions are more the creature of the communist system.

Connected with this, while their Soviet colleagues have had only attenuated contact with the West (surely since 1928, and perhaps since 1914-1917 in the main), East European scientists have been split off from the mainstream of the scientific community only since the period 1939-1947. The additional quarter century or more of contact may make a difference in the same way more recent experience with functioning markets appears to make a difference in the pace and popular acceptance of profound reforms in the economic sphere.

The other major difference, of course, is in the size of national science establishments. In spite of the impressive official statistics on percentage of population with higher degrees and on the number of scientific workers in the establishments of Eastern Europe, there is a vast difference in absolute size between these establishments and the

self-contained universe of the Soviet scientific and R&D hierarchies. The quantitative difference may be so great as to constitute a qualitative one. To state it as a hypothesis: As with much else in the orthodox Soviet model for economic development and social organization, what might exist as a cumbersome, perhaps inefficient, but ultimately workable system for the Soviet Union has a disproportionately ill effect on smaller countries. While autarky in economic development may have been a viable policy option for the Soviet Union, it was a disaster in the countries of Eastern Europe where it was adhered to. Similarly, perhaps maintaining a largely self-contained and self-sufficient scientific research facility is viable, with many qualifications, for the Soviet Union, while for the smaller East European establishments the relative lack of contact with other scientific communities leaves them enfeebled and/or overly dependent on the Soviet Union.

The shortfalls in both areas have been ameliorated by international contact and commerce through the instrument of CMEA. At least since 1971 and the drafting of CMEA's Complex Program the desirability of more intense scientific interaction between member states has been an increasingly central concern of CMEA. The early attempts, however, showed little result with a few exceptions.[10] Efforts at integration of scientific work and drawing together R&D communities reached their apogee in the Comprehensive Program of 1985 mentioned above. Below the five major directions for cooperation were listed 93 main tasks, divided further into no less than 629 specific projects.

What set the 1985 Program apart from its predecessors, according to the Soviets,[11] was the interconnection between the various research tasks, the emphasis on putting results into actual production, and the unifying concept of "direct ties" between Soviet and East European scientific and R&D establishments.

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[10]One of these was in the field of computer development, generally viewed in the early 1980s as a success by most countries with the possible exception of Poland, which felt its own progress was retarded by the cooperative effort.

[11]See the interview with G. I. Marchuk, *Pravda*, 29 December 1985.

The Program is too large a topic to discuss usefully here.[12] For the present purpose, it is interesting to note that the response to the Program varied among East Europeans. The fundamental concerns included a perceived danger of increased dependence upon the Soviet scientific and research hierarchy as well as skepticism over whether the results were likely to justify the costs to the participants. All of the head organizations for the 93 tasks were Soviet entities. Further, in spite of perceived mutual benefits ensuing from the cooperation, there existed potential Soviet unilateral benefits: gearing CMEA high technology output to best suit Soviet needs through the setting of standards; placing Soviet organizations in a better position to control East European R&D output and more effectively monitor the quality of intra-CMEA trade; and controlling, if not actively restricting, scientific and technology contacts with the West.

Bulgaria and Czechoslovakia signed on readily to the Program, the latter at some cost because of its already close economic and ideological dependence upon the Soviet Union. The Poles, who because of their economic travails were permitted to run a series of large deficits with the Soviets, were not in a position to be outspoken in their concern. Romania's Ceausescu was not so reticent and stated his opposition in vociferous terms, although this may have stemmed in part from having had a previous understanding with Chernenko on a Soviet raw material delivery *quid pro quo* going awry and not being made part of the final package.

The reticence of East Germany (GDR) and Hungary is most interesting. The East Germans believed the differential between the qualitative level of their scientific and R&D cadre and that of the Soviets would work to the detriment of their technological development. There might also have been a fear that the special relationship with West Germany, increasingly important to the GDR during the 1980s, might be jeopardized by too eager an acceptance of closer intra-CMEA cooperation. The Hungarian objection was more subtle but seems to have

[12]See Popper, 1991, for fuller treatment.

derived largely from the damage that might be done to two decades of Hungarian efforts to re-merge their scientific community with the larger international, and particularly Western, mainstream.

Whatever the ultimate effect of the Program might have been, the current moribund state of CMEA and the manifold questions about its future in any form have put implementation on permanent hold. The nature of cooperation and interaction in any form between scientists in the member states becomes a matter for renegotiation.[13] As these ties are sundered, so also are most present arrangements for multilateralism in East European research efforts. Some science areas (nuclear research, for example), even in countries like Hungary with an exceptional Western orientation, are heavily dependent upon contact and exchange with Soviet institutions and scholars. There is potential for creating a large void, not only in areas of collegial interaction, joint activities and data exchange, but also for access to research facilities and equipment not available in each East European country.

All of the research institutions of the former CMEA states will now be searching for new partners for research and alternative means of support and access to the global scientific community.[14] This may, then, provide the greatest difference between the fate of science in the Soviet Union and in Eastern Europe. On the whole the East Europeans dispose of fewer resources to attract potential science and technology partners. While for Soviet science, serious readjustment or even major retrenchments may be necessary, in Eastern Europe entire scientific disciplines may be on the brink of extinction (or at least of a savage pounding) because on their relatively small scale they may be unable to survive the limited access to financial and political resources that looms in the near term.

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[13]This will also have an effect on many East European equipment facilities like the laboratory for Low Temperature High Magnetic Field research in Wroclaw, Poland, funded 42% by the Soviet Union, and 25% and 8% respectively by East Germany and Bulgaria.

[14]In a single week in May 1990, the Hungarian Academy of Sciences applied to join CERN, the European Laboratory for Particle Physics, the European Space Agency, and hosted a US-USSR-Hungary forum on scientific cooperation and exchange (*New Scientist*, 4 August 1990, pp. 28-29).

III. TRANSITION: SOLUTIONS AND PITFALLS

The quest for a transition path toward a new system for supporting national scientific and technological development may be broken into two parts. The first step is to ask what each nation may require from its science and technology establishment to effect the larger transformation of the domestic economy. This begs the question of the time for transition and how soon positive results will be required. Putting this aside for the moment, there still remain substantial questions about the relationship between science and technology, and their relationship, separately and as a system, to economic development and international competitiveness. The answers to these questions have by no means been satisfactorily resolved in the relatively more stable world of the West.

It becomes particularly difficult during a period of such tumultuous change to ask what the positive role of science and technology may be in the economic transformation of the countries of Eastern Europe. Any enumeration of the input side of the ledger would show that the East European countries possess considerable human and capital resources in both science and technology development. Establishments are well-endowed with personnel and, in some instances, equipment (R&D expenditure taking a proportionately larger share of national income than is usual in the West), but are peripheral as far as the world scientific community is concerned.[1] Their inputs have failed to generate wealth-creating outputs because of a systemic inability to use resources, and especially information resources, effectively. For the countries lacking earlier scientific traditions, the past forty years have combined the phenomena of catch-up with relative isolation from other scientific communities except for the integration efforts brokered through CMEA.

[1]A study comparing the results of Finnish and Hungarian science shows that in spite of a similar level of research activity and publication, Hungarian science has much less influence as measured by scientometric means than does Finnish. The difference in level of international collaboration is cited as a main cause (Braun, et al. (1985).

These factors would seem to place the countries of Eastern Europe in the classic position of technological followers rather than innovators. As a matter of policy, then, would it be better to accept this situation or to try to achieve a breakout into the ranks of the technology leaders in some areas of comparative advantage? Various entry costs would impose considerable obstacles on the latter course. These countries might appear better placed to profit from the diffusion of innovations by taking up the classic position of product-cycle followers, assuming their economic houses can be put into order. Yet, to follow this course raises a specter of permanent dependency; it also calls into question the ability of the currently existing industrial structure to assimilate technology quickly and efficiently. These countries have suffered nowhere near so much from the technology embargo imposed by the West through COCOM as from their own systemic inability to elicit from capital equipment the fullest measure of capability embodied in the technology they do import (Popper, 1990).

Trying to capture a technological lead, because of resource limitations, will entail somehow identifying and generating winners. The experience of the past, both in the former Soviet bloc as well as in the West, has shown the difficulty of this strategy. Two main approaches may be identified. The first route would be the strategic management, "science policy," approach implicit in the "science leads" paradigm of science and technology. This would come quite naturally to East European policymakers since it requires choices to be made and implemented by a technology planning staff.[2] This would be a seductively dangerous course for any government to follow but especially counter-productive in an Eastern Europe desperately in need of fundamental change. Given the current situation, any attempts to move in this direction in Eastern Europe are likely to be overly hierarchical, to be laboring under the paradigmatic burden described in the sections above, and ultimately to be prone to making the wrong guesses.

[2]The MITI (Japan's Ministry for International Trade and Industry) of popular lore, rather than that of historical record, comes to mind as an illustrative example.

The problem with strategies based on the linear integrated model, even if one believes it captures the essence of science's role, is that one cannot know *ex ante* what bets will pay off and, more naggingly, when. In its essence, the strategic management route attempts to deal with the uncertainties inherent in technology development by imposing a structure on the future. Rarely do such efforts prove effective; the future seldom pays court to the exigencies of today. A multi-pronged approach to future technology assessment and development is more likely to allow more of one's bets to remain covered. The alternative, then, is to employ a less centralized, more opportunistic market-oriented strategy by maximizing the number of development centers to increase the likelihood of coming up with winning combinations. But this, again, is a game the East Europeans are currently less well-suited to play than are (potentially) the Soviets. It is precisely the relative paucity of alternative centers which distinguishes the East European technology development base. Even if this were not so, pursuit of this approach requires the existence of domestic consumers who are authoritative, in the sense both of being knowledgeable and sovereign over purchase decisions, to make international success even remotely likely. In other words, choices must still be made over what avenues would be fruitful to exploit. There are no mechanisms inherent in the science and technology institutions of Eastern Europe today, nor in the wider economy, to make these choices in an informed way. Once again, the connection between wealth-generating technological development and the *sine qua non* of profound economic reform appears ineluctable.

The "science on the market" approach also carries a potential cost depending on how sweepingly it is applied to existing assets. In institutes placed on a self-financing or *polnii khozraschet* basis in the Soviet Union and Eastern Europe, there have been complaints about the qualitative changes this status brings to research programs. (See Panova and Matveev, 1989). The initial response has been to be more result-oriented and to adopt a more short-term planning horizon. However, this reduces the amount of basic and, it is claimed, potentially path-breaking, but necessarily more risky, applied research.[3]

[3]It should be noted, however, that these changes have been undertaken in a system still adhering in the main to the tenets of

However this balance is resolved in the long term, in the foreseeable future the technology component of the science and technology system may receive most emphasis and priority. This is perhaps as it ought to be. The "science leads technology" development path, bespeaking a need for a large force in basic research, is not the only way to proceed. Yet, a drastic reduction in basic science funding would entail considerable cost in human terms and run the risk of frustrating the hopes of the generation of young researchers whose aspirations played a large part in bringing about the revolutions of 1989. Further, the fundamental problems of how to decide priority and determine what assets to let go remain.

This, then, raises the second major question surrounding the process of transition: namely, what the scientific and R&D establishments in Eastern Europe need from their respective nations in order to prosper. Clearly, the primary issue will be funding in milieus where the former financial arrangements have been, or are likely to be, completely overturned. Domestic resources alone are not likely to prove sufficient to maintain current establishments even after considerable transformation. All signs point in the short term to a need for greater research cooperation, joint ventures with foreign partners, and participation in international consortia. This applies equally to basic and applied research, but may be more crucial to the survival of the former.

Western involvement in East European science and technology has the potential for resolving more than just the financial crunch. Participation by Western governments and private commercial interests in the science and technology systems of Eastern Europe could prove crucial in helping determine where priority should be set for R&D activity,

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central planning, not one where risk-taking is likely to receive adequate reward. Even though, in practice, only "twenty out of a hundred projects are found to be successful" (Katsunov, et al., 1983), the planning process assumes a practical return for each. This inclines researchers to choose projects so as to modify risk ensuing from unknown and, by definition, unknowable elements. This leads to less than bold advances and low return on scientific investment.

which assets to develop and which to forego, how to orient applied research establishments toward the market, and how to fund basic research. This is perhaps the only avenue in the near term for achieving meaningful participation in multilateral endeavors and to become a part of the international flow in products and ideas.

In determining the actual form of cooperative assistance, it behooves both the East Europeans and their potential foreign partners, both sovereign and commercial, to treat the science and the technology components of the system more as separable, and less as antecedent and successor activities, in accord with the paradigm outlined above. This is not only because of the different nature of activity in each area, but also because such a distinction allows the exact role for each potential Western player to be made more clear. As a side benefit, this would go far toward reconstituting the institutions of Eastern Europe in a direction probably more favorable to efficient use of R&D assets but toward which, as has been suggested above, they would not otherwise seem to be historically or philosophically disposed.

Preservation of the *basic* scientific research base is important to a modern economy. Even if the second, coequal paradigm of science and technology is accepted, this does not relegate theoretical research to the same plane as opera—something the state should support because of its aesthetic and character-building values. The real contribution of public R&D spending is not so much the actual fruits of research as the skill-building that occurs as part of the process. This process of training in the sciences is a necessary support for a higher level of technology activities (Pavitt, 1988). This, again, suggests strategic science may be too myopic to make education a primary focus and so may prove debilitating in the long run.[4] This is also a danger when basic science is excessively caught up in commercial competitive issues.

[4]It also suggests a possible source of technological weakness in the standard East European model of separating Academy research from the university's education function.

"Big Science" projects and disciplines would not seem to loom large in the immediate futures of East European scientific establishments, and this is perhaps as it should be. Yet, it is entirely possible that even what is worthy in these establishments may not be preserved over the short term without cooperative arrangements with Western governments and institutions. Cooperation may take many forms, ranging from exchanges and fellowships to actual cooperative research agreements between partner laboratories or institutes.[5] Contacts with, and Western assessments of, individual labs and workers will become crucial. In effect, an external selection factor will play a large part in helping local governments determine which of their assets are worthy of support and exploitation. In an era when Western governments are searching for ways to support Eastern Europe without compromising the pressures forcing change, this may prove one of the most fruitful areas for consideration.[6]

A similar connection with the West might prove crucial as a means for East European *applied* R&D personnel and institutes to escape the binds they find themselves in. But here the principal instruments should be joint ventures with and direct investment by Western commercial interests, not governments. These have the potential of providing vital funding resources while obviating the problems caused by fungibility and the indiscriminate targeting characteristic of other means of resource transfer. Formal contracts and agreements with foreign businesses familiar with the management and maintenance of effective research facilities would also go quite far in providing a tie-in to multilateral research efforts and easing the process of

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[5]This need not be viewed as a one-way street nor as entirely eleemosynary. In return, the Western partner receives the active participation of highly skilled researchers who, because of their very poverty, often excel their Western counterparts in experimental design and sensitivity to the instruments.

[6]The United States was of considerable help to both Taiwan and South Korea in building technology infrastructure. Science attache's were active in promoting contacts and provided advice and seed money in founding institutions for research. The demonstration effect from relatively small Western government outlays in Eastern Europe may be similarly profound.

rejoining the international research community as fully participating members.

The Western partner would provide more than just money in return for use of a country's research assets. Lack of well-developed domestic markets, decades of enforced isolation, inexperience with techniques for management and priority choice consistent with the production of technologies suited to the needs of customers, and the institutional legacy left by an overtly ideological orientation to development leave the East European R&D establishments distinctly unprepared to make the choices facing them. They are underequipped to compete in the game of identifying and developing winners. The Western commercial partners can fulfill many of these functions. For years the East Europeans have been able to develop commercially useful technologies without the ability to recognize or exploit them.[7] The Western partner will provide the marketing and technology assessment infrastructure to fill the gap. In the course of this process, disembodied technology for management will be transferred.[8] The potential exists for creating new training systems, a restructuring of the science management infrastructure and the policy-setting processes (peer review, etc.), research management, marketing, helping to modernize and retrofit those branches of industry worth saving—and perhaps more important, to tacitly indicate those areas it would be best to scrap—and generally demonstrate how applied research can be used to make traditional industries competitive.

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[7]A good example is the development of soft contact lens. The technology was developed in Czechoslovakia. It took a Western commercial partner to recognize the potential and commercialize the result.

[8]Various embodied forms of technology will also be transferred. This raises a potential problem for Western government policy as well as an important area for research. However, there is danger for some in the West to overplay the importance of technology transfer in solving Eastern Europe's problems. Among other things, this plays into the hands of those who still insist the COCOM embargo was a large source of the region's difficulties and distracts from the true problem, the system itself. Further, the potential for East-to-West technology transfer is frequently ignored.

The extent of Western involvement and the outcomes likely to ensue are, at this writing, highly speculative. Much depends upon the attitudes of the East Europeans and their true willingness to change. The interest is at least present in the West and has been demonstrated by the number of ventures entered into already, the even greater number of firms expressing interest in more substantial efforts, and in government support through such measures as the SEED Act. This all need not necessarily come to pass, however. The East Europeans may find this approach too costly to entertain in domestic political terms. If this helping hand is not firmly grasped, however, there may be little chance of saving domestic science solely through local means; these countries may then find it impossible to truly live up to the technological potential they have, over the years, sacrificed so much to build.

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